Dutch Elm Disease:

Status of the Disease, Research, and Control, 1977

Forest Service
U.S. Department of Agriculture
July 1977

DUTCH ELM DISEASE:

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Research, and Control, 1977

Prepared by the Forest Service in cooperation with
Agricultural Research Service,
Cooperative State Research Service,
and Extension Service.

Based on a report to the President and Congress of the United States, prepared in accordance with Section 20 of the National Forest Management Act of 1976.

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SUMMARY

Section 20 of the "National Forest Management Act of 1976" directed the Secretary of Agriculture to conduct a study of Dutch elm disease and prepare a report that (1) provides information on the incidence of the disease, (2) evaluates present methods of control, (3) describes plans for further research to control the disease, and (4) presents an action plan that includes a program of outreach and public information about Dutch elm disease, and recommendations for controlling the spread of the disease. Additional information was requested by Congressmen Fraser and Nolan and is included.

Dutch elm disease (DED) is a vascular wilt that was introduced into the United States in 1930 from Europe. DED is caused by a fungus, Ceratocystis ulmi (Buisman) C. Moreau, which is transmitted by two bark beetles: the smaller European elm bark beetle, Scolytus multistriatus (Marsham); and the native elm bark beetle, Hylurgopinus rufipes (Eichhoff). The European species is the principal vector (carrier) in most of the United States. Spread from diseased to healthy elms also occurs through root grafts.

The disease has been reported in all States except Florida, Louisiana, New Mexico, Arizona, Utah, Nevada, Washington, Hawaii, and Alaska. Incidence is highest in the Northeast where in 12 States over 75 percent of the elms in municipalities have been lost. There were an estimated 77 million elms in incorporated areas just prior to 1930. By 1976, an estimated 34 million remained, a reduction of 56 percent.

The causal fungus, its insect vectors, and methods of control are being investigated by Federal, State, and university organizations. In FY 1976 total Federal expenditures for DED research were $1,319,818. Comparable expenditures are expected in FY 1977. Proposed FY 1978 Federal funding for research is $1,369,400.

Ongoing research is concerned with the development of: (1) Systemic fungicides for control of the fungus; (2) chemicals for the control of insect vectors; (3) elms resistant to DED and/or beetle vectors; (4) biological control of the fungus; (5) biological control of the insect vectors; (6) techniques to assess the variability of the causal fungus on effectiveness of control techniques; and (7) improved methods of sanitation, tree pruning practices, and reduction of root graft transmission of the fungus. No single approach can control the disease. Research is designed to provide a variety of tactics and strategies for control that are cost effective, biologically sound, and environmentally safe.

Coordination of research in the Department of Agriculture is achieved by several means. Improved coordination can best be obtained through strengthening of the Agricultural Research Policy Advisory Committee (ARPAC). ARPAC provides the bases for State and Federal cooperation in planning and implementing regional and interstate research programs. Membership on ARPAC includes the administrators of agricultural and forestry research in the universities as well as the administrators of the agencies in the Department that are concerned with Dutch elm disease. The Extension Committee on Organization and Policy (ECOP) coordinates national Extension programs.

Presently used control methods ranked from the least effective (producing virtually no control) to the most effective (loss of 1 to 5 percent of elm population per year) are: (1) Removal of diseased trees from 1 to 3 years after death, (2) removal of dead trees before the next growing season, (3) sanitation and removal of dead and dying elms within 30 days of detection, (4) sanitation plus insecticidal spray programs to protect healthy elms, and (5) sanitation, spraying with insecticide, and treatment of root grafts. Variation in the success of the more effective methods is caused by (1) failure of authorities to comprehend the gravity and urgency for survey and control when DED is first discovered, (2) lack of concern for a small population of elms resulting from low initial numbers or from mortality due to DED, (3) lack of funds, and (4) failure to persistently apply the most effective control methods.

A control program is most beneficial if implemented when the disease is first detected. To be effective, the program must be designed to reduce the annual rate of mortality to 5 percent or less of the remaining elm population. The recommended control programs must encompass all susceptible elms, public and private alike, and include: (1) Extensive aerial and complete ground surveys during the summer to detect diseased elms; (2) prompt removal and destruction of all diseased and dead elms to prevent bark beetle population buildup; (3) spraying the entire elm population in the spring using methoxychlor; and (4) treatment or severance of root grafts between diseased and healthy elms.

The Department of Agriculture Organic Act of 1944 (58 Stat. 735, as amended; 7 U.S.C. 147a) authorizes the Secretary to carry out operations or measures to detect, eradicate, suppress, control or to prevent or retard the spread of plant pests, including DED. The Secretary may enter into cooperative agreements to carry out the provisions of this section. The Department has had no active DED survey and control program since the quarantine to prevent domestic spread was rescinded on April 1, 1947, and the quarantine to prevent foreign importation was rescinded on April 15, 1966. The quarantines were rescinded following assessments that the natural spread of the DED could not be practically prevented.

Municipal control programs, costing an estimated $30 million annually, now protect approximately 1.8 million elms out of an estimated 24.4 million elms that might be protected with additional resources. The benefits of control were recently demonstrated when a 15-year examination of annual expenditures by 39 communities with DED-infected elms showed that control programs cost from 37 to 76 percent less than the cost of removing DED-killed elms where no control was attempted.

In considering Federal participation in municipal DED control programs, the principal alternatives are (1) technical assistance and extension education, (2) technical assistance and extension education plus revenue sharing to finance control activities, and (3) technical assistance and extension education plus cost-sharing of control activities. Technical assistance and extension education would encourage additional municipalities to protect their elms, resulting in the protection of up to 1.9 million elms at a total annual cost of $36.8 million. Revenue sharing funds may be used to finance DED control or to match Federal cost-sharing funds. Federal cost-sharing alternatives range from 25 to 50 percent Federal share. Technical assistance, extension education, and 25 percent Federal share would help protect an estimated 7.6 million elms at a total annual cost of $133.1 million while technical assistance and 50 percent Federal share would protect an estimated 13.2 million elms at a total cost of $229.4 million annually. It must be emphasized, however, that local commitment, which can be achieved through local funding, is critical to the success of a program.

The plan developed for outreach and public information on DED is intended to inform small communities, municipalities, landowners, and the public of the history, incidence, and severity of DED, and to inform them of the importance of controlling the disease with the latest control methods. The plan would be implemented through existing information organizations in the Department of Agriculture. Total costs are estimated at $2,555,000 over a 5-year period.

The general objective of the range of alternatives for Federal participation in a national program is to reduce the loss of elms so as to provide time for newly planted non-susceptible species to grow and for research to investigate alternative strategies for direct and indirect DED control. We must recognize, however, that although current control techniques may reduce annual elm losses to as low as 1 percent, the continued loss of elms to DED is a certainty.

INTRODUCTION 1/

Section 20 of the "National Forest Management Act of 1976" (Public Law 94-588) directed the Secretary of Agriculture to conduct a study of Dutch elm disease (DED) and prepare a report as follows:

> "The Secretary of Agriculture, in consultation with officials of both the States and political subdivisions thereof, shall conduct a study of the incidence of Dutch elm disease and evaluate methods for controlling spread of such disease. The Secretary shall prepare and submit to the President and both Houses of Congress on or before March 1, 1977, a report which includes--
>
> (1) results of such a study;
>
> (2) plans for further research into the control of Dutch elm disease; and
>
> (3) an action plan that includes a program of outreach and public information about the disease, and recommendations for controlling the spread of the disease."

In addition to the information required by the Act, Congressmen Donald M. Fraser and Richard M. Nolan requested that the following be included in the report:

a. Comparative cost analysis of early versus later control programs in selected States and localities.

b. Estimated expenditures for control and/or sanitation.

c. Alternative State-Federal funding arrangements with cost/benefit analysis for each alternative.

d. Bibliography of publications on DED.

e. Evaluation of alternative arrangements for coordinating research and bibliographic efforts.

In compliance with Section 20 of the National Forest Management Act of 1976, and requests, the following report on DED was prepared.

1/ Mention of a proprietary product in this report is for reader's information only and does not constitute endorsement by the U.S. Department of Agriculture to the exclusion of other similar products.

PROCEDURES

The Secretary of Agriculture designated the Forest Service to coordinate this study and prepare a report obtaining information from the Agricultural Research Service, Cooperative State Research Service, and the Extension Service.

Each agency was requested to provide answers to the following questions regarding DED control and research:

(1) What is your appraisal of existing DED control strategy?

(2) What is your ongoing research including plans for FY 78?

(3) What additional research is needed to significantly improve DED control capabilities?

In addition to the above agencies in the U.S. Department of Agriculture (USDA), information was requested from the States and political subdivisions listed in appendix A.

The State agencies were asked to:

(1) List counties with DED.

(2) Estimate the number of elms within municipalities of the State prior to the detection of DED and as of 1976.

(3) Estimate current annual statewide expenditures for DED control.

(4) Evaluate the major obstacles to an effective disease control program.

(5) Suggest effective methods for an outreach program to inform arborists, city governments, and the general public about DED and its control.

These data and the responses were compiled and analyzed for inclusion in this report. Each of the above USDA agencies, and the Animal and Plant Health Inspection Service reviewed this report.

HISTORY AND DESCRIPTION OF DUTCH ELM DISEASE

Dutch elm disease (DED) is the most destructive shade-tree disease in North America. DED, which was first discovered in the United States in Ohio in 1930, was introduced on elm veneer logs imported from Europe. The fungus causing the disease infects all native elm species and some introduced species. Unfortunately, the American elm (*Ulmus american* L.) is the most susceptible species.

The disease, classed as a vascular wilt, is characterized by a gradual wilting and yellowing of the foliage, usually followed by defoliation and death of affected branches, and finally by death of the whole tree. Less frequently, the entire crown may express symptoms almost at once. This process can take from 1 to 3 years, but usually affected trees die within a year, and often only a few weeks after symptoms first appear. Not all elms react the same to the causal fungus and there is some variation in fungal virulence (capacity to cause disease) resulting in varying degrees of symptom development and rate of dying.

The actual wilt is caused by the blockage of the sap stream resulting from the action of a pathogenic fungus, *Ceratocystis ulmi* (Buisman) C. Moreau, which is introduced into the sap stream of twigs or small branches during feeding by two species of bark beetles. These insects--the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), and the native elm bark beetle, *Hylurgopinus rufipes* (Eichhoff)--fly from their breeding sites in logs containing the fungus and transmit the fungus into the twigs as they feed. The European species is the principal vector (carrier) in most of the United States; its life cycle is shown in figure 1. Throughout this report the term "elm bark beetle" or "bark beetle" refers to the European elm bark beetle.

The disease and resultant death of elm trees are thus brought about by a complex interaction of fungus, insect vector, and host tree. This interaction is influenced by fungus variability, elm species, elm bark beetle population, distance between trees, and climate. In addition, once the disease is established in a municipality or elm grove, its spread is enhanced by fungal growth through root grafts between diseased and healthy trees.

The disease kills very few elms the first 2 to 4 years after becoming established in a community. However, as the elm bark beetle population and inoculum (fungus) builds up, the mortality rate (without controls) may reach 10 percent or more of the remaining elm population per year. It is not uncommon for 50 percent or more of the elm population in an area to be killed over a 10-year period.

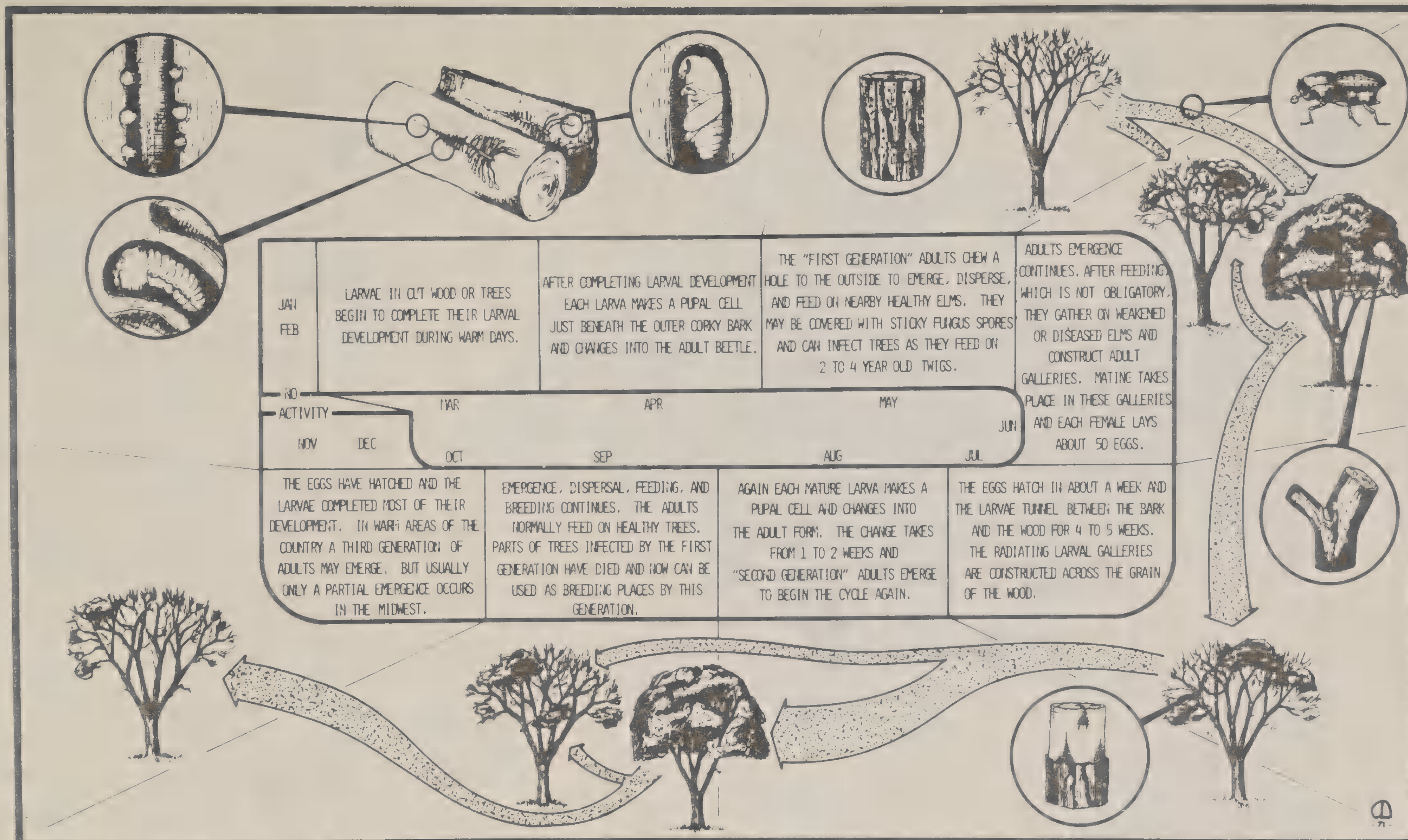

Figure 1.--**The life cycle of the smaller European elm bark beetle. Variations in timing may occur in different geographic locations.**

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DISTRIBUTION AND INCIDENCE OF DUTCH ELM DISEASE

Since 1930, Dutch elm disease (DED) has spread to 41 States from coast to coast. The only States not reporting the disease are Florida, Louisiana, New Mexico, Arizona, Utah, Nevada, Washington, Hawaii, and Alaska. Twenty-three States (mostly in the Northeast and Midwest) have DED in every county (fig. 2).

The incidence of DED, measured in percent of trees lost, is highest in the Northeastern States and lowest in the Southern and Western States. Twelve States, all in the Northeast, have lost over 75 percent of the elms in municipalities. Of the 16 affected States west of the Mississippi River, 12 have lost less than 25 percent, and 9 of these have lost less than 5 percent (fig. 3 and 4).

The percentage of trees killed is closely related to the length of time DED has been present in a State (table 1). In the States where DED was discovered during the past 10 years, an average of 95 percent of the elms remain. Where DED was reported 21 to 30 years ago, an average of 32 percent remain. These are statewide figures rather than for individual incorporated areas.

Table 1.--Relationship between years since discovery of Dutch elm disease and remaining elms

Years since DED discovery	States	Average elms remaining
	number	percent
1-10	11	95
11-20	9	68
21-30	7	32
31-47	14	23

There were an estimated 77,000,000 elms in incorporated areas of all States just prior to introduction of the disease into the United States in 1930. By 1976, however, an estimated 34,000,000 remained, a reduction of 56 percent (fig. 3).

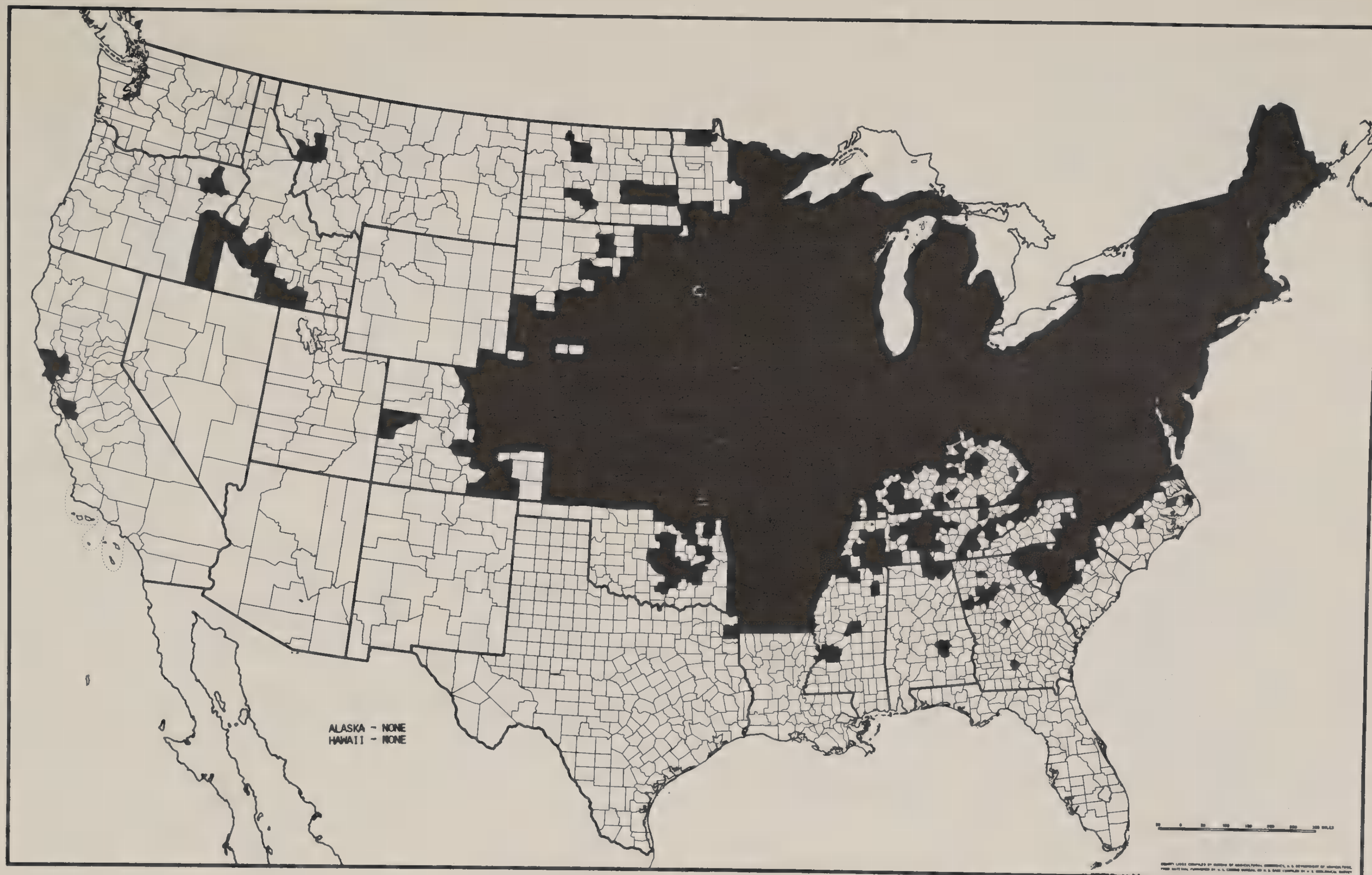

Figure 2.--Distribution of Dutch elm disease in the United States, 1976.

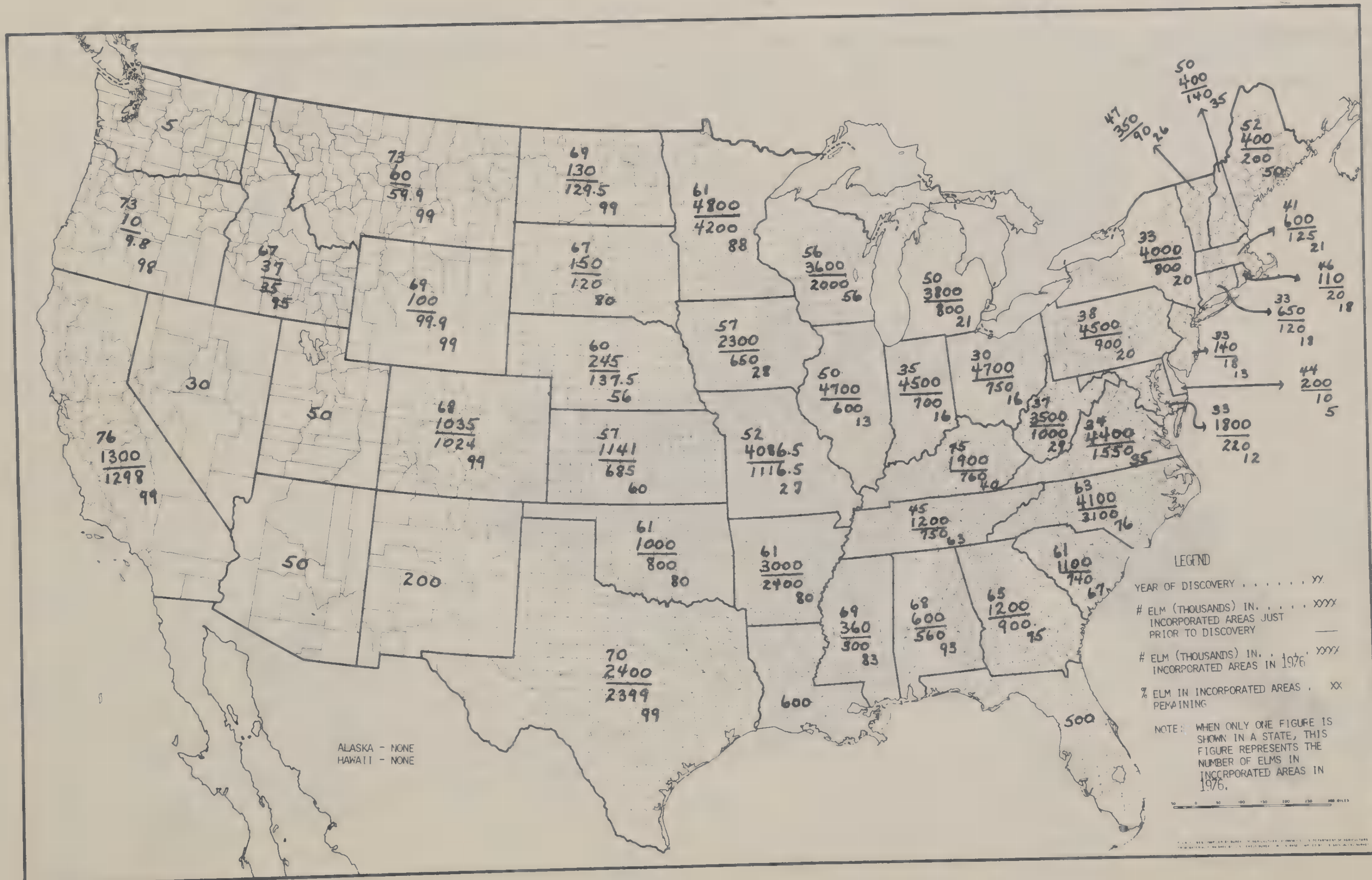

Figure 3.--Detection and incidence of Dutch elm disease in the United States, 1976

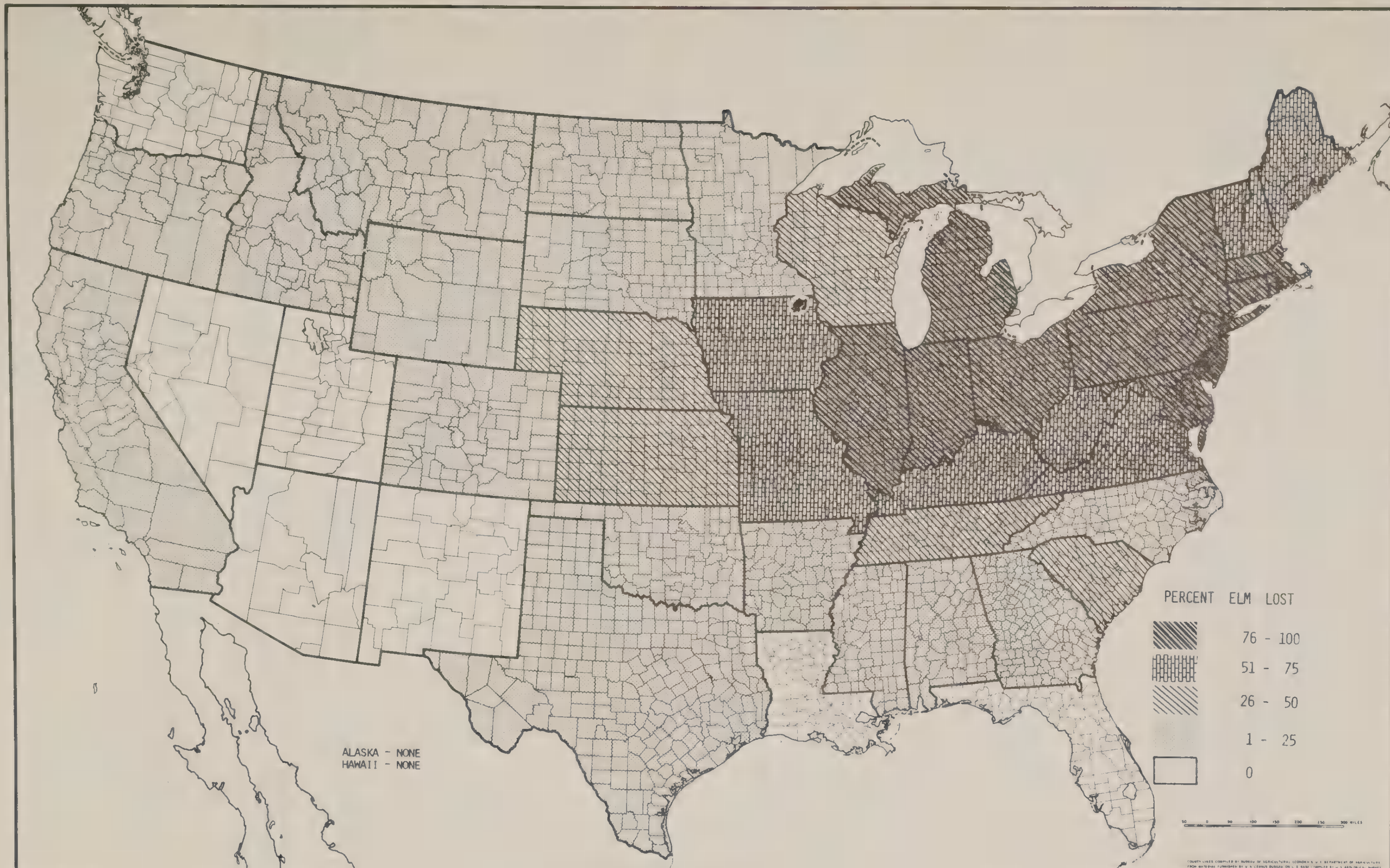

Figure 4.--Mortality due to Dutch elm disease in incorporated areas in the United States, 1976.

RESEARCH ON DUTCH ELM DISEASE

Dutch elm disease (DED) has been studied in Europe for over 75 years. In the United States, the causal organism, its insect vectors, and disease control have been investigated by Federal, State, and university organizations since 1930. The status of current research, additional research needs, and coordination of research and technical information is summarized in the following section.

Current Research Programs

The appropriations and manpower for DED research in the USDA are summarized in table 2 by agency and fiscal year.

Table 2.--Funding and scientist years for DED research

USDA	FY 1975		FY 1976		FY 1977[1]		FY 1978[2]	
Agency	Dollars	Scientist Year	Dollars	Scientist Year	Dollars	Scientist Year	Dollar	Scientist Year
ARS	319,500	4.6	452,818	4.8	392,200	5.2	405,400	5.2
CSRS	278,000	5.1	282,000	5.3	304,000	5.7	[3]334,000	6.3
FS	546,000	7.0	585,000	7.0	622,000	8.7	630,000	8.5
TOTAL	1,143,500	16.7	1,319,818	17.1	1,318,200	19.6	1,369,400	20.0

1/Estimated.
2/Represents proposed appropriation.
3/Based on anticipated fund increase of 10 percent over 1977 level.

A list of research projects and studies on DED supported by Federal funds is provided in Appendix B. In addition to research conducted at Federal laboratories by the Agricultural Research Service (ARS) and the Forest Service (FS), the Cooperative State Research Service (CSRS) funds research at 11 universities; the Forest Service, through cooperative aid agreements, funds research at 2 others.

Current research can be grouped into seven general categories:

1. Evaluation of Lignasan BLP (methyl 2-benzimidazole carbamate phosphate) and new systemic fungicides for control of the pathogen.

2. Research on insecticides, pheromones (sex attractants), and other behavioral compounds (feeding stimulants and deterrents) for chemical control of the insect vectors.

3. Development of elm varieties resistant to DED and/or the bark beetle vector.

4. Studies of avirulent (nonpathogenic) strains of the fungus and antagonistic microorganisms for biological control of the pathogen.

5. Investigation of parasites and predators for biological control of the insect vectors.

6. Determination of the variability of the pathogen (fungus) and the effects of this variability on disease incidence and severity, and tolerance to fungicides.

7. Studies of improved sanitation and tree pruning practices, and reduction of root graft transmission.

The objective of the research is to provide cost effective, biologically sound, and environmentally safe strategies for controlling DED. The research described below will yield additional technology for improved control strategies within the next 5 years.

Systemic fungicides injected into diseased elms to arrest development of fungus and "save" the trees have shown great potential as a control procedure. A technique using high pressure injection and the promising systemic fungicide, Lignasan, is now undergoing additional field tests. Experimental success with this technique has been variable and limited to trees with symptoms on less than 30 percent of the branches. Further development and refinement of this control technique is necessary before it can become a standard operational procedure. It should also be noted that the DED pathogen has shown a high degree of tolerance to Lignasan in laboratory studies so currently research is investigating: (1) How this tolerance develops in the fungus, (2) the stability of the tolerance, (3) the impact on disease control with Lignasan when elm trees are inoculated with tolerant fungus strains, and (4) the development of new water soluble fungicides and improved formulations and injection techniques.

A naturally occurring fungitoxicant, decanoic acid, has been found in the seeds of American elm. Studies are also in progress to isolate and identify fungitoxicants from the leaves of resistant,

juvenile American elms. Chemicals of this type promise to be less toxic to elm trees and less injurious to the environment than present synthetic fungicides, but their practical importance has not been demonstrated.

Chemical control of the bark beetle vectors can be accomplished by spraying an insecticide, such as methoxychlor[2/], on the feeding and breeding sites. This reduces the transmission of the disease and lowers population levels of the beetles. Improved insecticides, insecticide formulations, and application techniques are results anticipated from continuing research. The research could develop suitable replacements for methoxychlor and more economical and efficient methods for achieving complete insecticidal coverage of treated elms.

Pheromones and other natural or synthetic compounds, which affect the behavior of the insect vector, may be useful additions to control by pesticides. These chemicals may be used either singly or in combination with insecticides to achieve optimum control of the insect vectors. The pheromone of the European elm bark beetle has been identified, and a synthetic mixture, "Multilure," shows promise as a chemical for beetle control. A practical system for beetle surveillance with synthetic attractant pheromones is being developed. This technique would allow users to determine beetle emergence periods, beetle population levels, and the presence of spore-carrying beetles in areas of low beetle or disease incidence. Programs to control the beetles and thereby the disease would be timed and applied accordingly. Pheromone trapping may also have practical application for control of beetles, when mass trapping is applied as an adjunct to sanitation and insecticide spray procedures.

Disease resistant varieties are an established approach for control of tree diseases. Some species of elm are more resistant to DED than others, and crossing and breeding programs have resulted in the development of several resistant varieties. One hybrid, the "Urban Elm" will be released in the near future. Also, a disease-resistant selection of American elm is in final stages of testing and will be released to the nursery trade when sufficient stock is available. Additional clones of resistant elms are under study. A selection program also has been initiated to find American elms that are resistant to elm bark beetle feeding. Beetle-resistant trees could be as effective in a control program as are varieties that are resistant to the fungus. Disease- and beetle-resistant varieties must have desirable form and be able to survive the often severe urban environment if they are to be acceptable.

2/Schreiber, L. R., and J. W. Peacock. 1974. Dutch elm disease and its control. Forest Service and Agricultural Research Service, U.S. Department of Agriculture, Agric. Inf. Bull. 193, 16 p.

It is anticipated that one or more new disease- and/or beetle-resistant elm varieties or hybrids will be released during the next 5 years. These resistant elms will retain many of the desirable characteristics of rapid growth, pleasing form, and tolerance to urban environments that make elm the premier urban street tree. Such resistant elms could provide new possibilities for the replacement of elms killed by DED as well as for planting in newly developed residential areas. By lowering the density of susceptible trees in a community, resistant elms would indirectly affect the control of DED by reducing the populations of susceptible elms.

Studies of improved methods of elm propagation are part of the tree breeding program. Resistant varieties or species vary greatly with regard to vegetative propagation. However, techniques have been developed that have increased the efficiency of propagation by both grafting and rooting of cuttings. These improved techniques should expedite providing resistant trees to the nursery industry.

Biological control of the pathogen is a relatively new approach to the control of DED and the potential is yet to be demonstrated. Investigations are being undertaken to determine the possible effectiveness of avirulent (nonpathogenic) strains of the pathogen in competing with virulent strains in the host tree. Evidence also exists that less aggressive strains of the fungus may be infected by viruses. Research is in progress to determine whether viruses can be used to biologically control the fungus. Antagonistic bacteria are also being investigated for their ability to reduce disease severity in infected elms. Bacterial antagonists have been isolated and are now being introduced into elms to determine if they will (1) multiply in the host and (2) reduce disease severity in infected elms.

Biological control with parasites and predators have the potential to reduce populations of bark beetle vectors and thereby serve as an adjunct to other control methods. Research is being conducted to identify the most promising parasites and predators (native and European) and to determine their effectiveness in reducing beetle populations.

Variability of the causal fungus could disrupt long-term control strategies. Recently, an apparently new strain of the fungus was discovered in Europe. Studies have shown that this strain is highly virulent in elms previously judged to be resistant to DED. The presence of such virulent strains in the United States could have profound effects on the development of resistant varieties of elm. Also, some strains of the fungus are tolerant to the fungicide Lignasan. Such tolerance could reduce the effectiveness of DED control by systemic fungicides.

Sanitation, the removal of all or parts of diseased trees, is the cornerstone of DED control. Sanitation contributes to the reduction in the amount of fungus available for transmission as well as a reduction in breeding sites. Research is being devoted to improving present practices of detection so that sanitation can be carried out promptly. Work is also underway to develop methods for reducing bark beetle breeding when diseased trees and wood cannot be removed promptly. There is also research into the use of deep girdles around the trunk of infected trees to prevent fungus movement into and through grafted root systems.

In addition to current research programs, some new research studies could be initiated. The additional resources have not been estimated at this time. Areas for consideration are: (1) Techniques for evaluation of DED control strategies, including the development of systems for modeling, beetle population sampling, and population dynamics; (2) studies of the physiology of fungus parasitism to determine how water supply is disrupted in diseased trees, how resistant and susceptible trees differ in their anatomy and chemical responses to infection, and how resistance is expressed in trees; (3) studies to isolate and identify the attractant pheromones and other behavior-modifying chemicals of the native elm bark beetles; (4) studies in biological control of DED, particularly using less aggressive isolates of the fungus; (5) determination of naturally occurring substances that inhibit the growth of fungus in resistant elms and particularly in all seedling elms that are presently universally resistant; and (6) studies on the relationship of DED to elm phloem necrosis that may be as detrimental to elms as DED.

It is unlikely that DED can be controlled by a single approach. A variety of tactics and strategies are needed that, when combined into integrated control practices, can effectively reduce the impacts of DED on urban environments. The program of research in the U.S. Department of Agriculture is aimed at providing the technology essential to improve control of DED.

Research conducted by the USDA with appropriated funds is centered in three agencies--Agricultural Research Service (ARS); Cooperative State Research Service (CSRS); and Forest Service (FS). As requested by Congressmen Fraser and Nolan, the coordination of Dutch elm disease (DED) research in the USDA is discussed below.

Research on DED conducted or funded by the USDA could be coordinated in several ways. For example, one agency could be designated as the lead agency responsible for overall coordination; all research on DED could be assigned to one agency; or, current mechanisms for coordination could be strengthened.

The ARS and FS conduct research on DED in Federal laboratories and also fund research at universities in support of their program missions. The CSRS administers Federal funds for agricultural and forestry research conducted by State universities. Each of the agencies serves a somewhat different constituency. The varying but complementary approaches to resolution of the DED problem foster scientific inquiry and technological advances.

Within the scientific community, awareness of current DED research is maintained by a number of means. In addition to personal communications, scientists concerned with DED participate frequently in regional, national, and international meetings at which research findings are presented and discussed.

The USDA Current Research Information System (CRIS) also provides means whereby scientists and administrators are informed on DED research. Through CRIS, pertinent information concerning individual projects on DED can be rapidly retrieved. The information in CRIS is updated yearly to provide information on the scope of the research and the advances attained.

Most university and USDA research on DED is encompassed by two regional projects:

1. NE-99. Biology and Control of Vascular Diseases of Plants. Participation includes six universities in the Northeast, and the ARS and FS facilities at Delaware, Ohio. In addition, three universities in the Northcentral region and one Western institution (University of California) participate.

2. NCR-32. Vascular Wilts of Forest and Shade Trees. Participation includes seven universities in the north-central region, ARS and FS at Delaware, Ohio, and the University of Nebraska. A number of additional State and public cooperators also participate in this program.

The establishment of the Agricultural Research Policy Advisory Committee (ARPAC) by Secretary's Memorandum No. 1657 has greatly strengthened research planning and coordination in the scientific community. Membership includes administrators of agricultural and forestry research in the universities and the administrators of several agencies in USDA including the Agricultural Research Service, Cooperative State Research Service, Extension Service, and Forest Service.

An objective of ARPAC is to "...develop further the bases for State and Federal cooperation in planning and implementing regional and interstate research programs..." This objective is effected through the formation of either standing subcommittees or *ad hoc* groups for particular tasks. A joint State-Federal leadership that characterizes ARPAC functions is a strong stimulus to realistic and active cooperation in all aspects of research including research on DED. The Regional and National Agricultural Research Planning System established by ARPAC in 1971 also strengthens research planning and coordination regionally and nationally.

Through ARPAC and the two regional projects on DED, ways are available for planning and coordinating research on this disease. These mechanisms are in place. They are proving to be effective in directing the course of research on DED.

Technical Information Retrieval

Over 75 years of concern for the Dutch elm disease (DED) and research on its causal organism, insect vectors, and control are embodied in more than 1,900 published articles and uncounted numbers of unpublished reports. Reports of general observations and research results have appeared in a broad range of outlets including scientific journals in English and several other languages, Federal and State experiment station publications, trade journals for arborists and pest management specialists, Cooperative Extension Service publications, popular magazine articles, and newspaper articles. A full knowledge of a significant portion of this literature is of great importance to avoid unnecessary duplication of research and maximum application of technology for control of DED.

Access to the current literature on DED is not difficult. The most significant literature has been published within the past 5-10 years and can be readily recovered. The plethora of scientific journals, abstracting journals, and the popular media are well represented in agency and university libraries. Agencies and many research scientists have lengthy distribution lists for reprints of separate articles; copying services are readily available to all. Access to the historical information (publications more than 20 years old) may be more difficult. However, major bibliographic works, e.g., Laut and Schomaker[3/] give lists of citations with broad coverage.

3/ Laut, J. G., and M. L. Schomaker. 1974. Dutch elm disease--a bibliography. Colorado State Forest Service, Colorado State University, 95 p.

Modern technology provides opportunities for more efficient ways of retrieving and presenting broad data bases such as for DED. An ideal technical information system would deliver in a relatively short time (days) complete and accurate citations of published literature with abstracts of the more important documents. Such a system would be highly useful to research scientists and control specialists.

Although technical information systems are available from commercial sources, the information supplied often needs to be supplemented to be fully useful. The Forest Service is developing a resource-oriented system, Renewable Resources Technical Information System (RRTIS), especially suited to the need. Current publications from Forest Service research scientists become entries in RRTIS. Except for a trial run to demonstrate the potential of the system, no concerted effort has been made to incorporate the full data base on DED in RRTIS.

A modest investment (relative to past and current costs of research and control on DED and property values) is needed to bring the worldwide literature on DED into RRTIS. The system has been designed and guidelines for preparing input and obtaining outputs are available. Resources are needed for a technical specialist (plant pathologist or entomologist), and for clerical assistance to prepare input to the system and to provide services, and operating funds are needed for processing. Any specific bibliographic effort on DED should be entered into a system such as RRTIS to facilitate exchange of information with similar systems nationwide and worldwide.

SURVEY AND CONTROL PROGRAMS

Evaluation of Current Survey and Control Methods

Survey Methods

The following methods of surveying for DED are presently used in various parts of the country. They are presented in order of the least effective to the most effective:

(1) Casual ground observation of all tree species for damage. This is the least effective method of detecting DED since a specific survey is not made and diseased elms are not singled out. About 30 percent of the elms showing DED symptoms are detected using this method.

(2) A single ground survey for DED each year, conducted during June or July. The best time for detecting DED is soon after the spring flight of elm bark beetles. Using this procedure, about 50 percent of the total DED infected elms are located.

(3) Three ground surveys each year, usually conducted in June, July, and August. These surveys find the elms which were: (a) infected the previous late fall; (b) infected after the spring beetle flight; and (c) infected after the summer beetle flight, respectively. Approximately 80 percent of the total DED trees are detected with this system.

(4) Continuous ground surveying from June through September. This results in each tree being surveyed four or more times each year. More than 90 percent of all DED trees are detected with this system.

Many States and municipalities in the Northeast follow method #1 or #2 because the majority of the elms have died. (DED has been present in these States about 40 years). Methods #1 and #2 are also primarily used in the Southern States where a large portion of the shade trees are species other than elm. Methods #3 and #4 are used by municipalities in several Western and Midwestern States where elms still constitute a large percentage of the total shade tree population.

Some States, for example, Washington and New Mexico, and municipalities in Minnesota, Oregon, and California, which are near known sources of DED, but have not detected it, conduct surveys for the elm bark beetle. This practice helps to locate probable future DED infection sites.

Control Methods

The following methods of control are now being used.

(1) Sanitation involves the removal and disposal of all dead and dying elm trees, branches, or wood that has the bark intact to eliminate bark beetle breeding sites. Sanitation practices should be performed within a few days of detection. Sanitation is an effective control if it can be thoroughly applied to an entire elm population. The problem is that complete and timely sanitation often is impractical because of the logistical problems of locating and disposing of the diseased trees before beetles emerge.

(2) Sanitation plus a chemical spray. The spray phase involves spraying the entire tree crown with an early spring application of methoxychlor to prevent beetle feeding in healthy elms.

Chemical spraying with methoxychlor is effective if thoroughly applied. Complete coverage of all the branches, however, is seldom achieved. The problems include wind, cold temperature, restricted placement of spray equipment because spring thaws and rains make the sod soft, and location of trees with respect to buildings and other physical obstructions. Another drawback of spraying is that adverse environmental impacts cannot be completely eliminated.

(3) An integrated method which includes sanitation and spraying as in (2), plus chemical or mechanical severance of roots to prevent spread of the fungus through root grafts between diseased and healthy trees.

Severance of root grafts between diseased and healthy trees is effective in preventing underground tree-to-tree spread. These treatments, however, are not applicable in many situations. Paved sidewalks and roadways prevent getting at grafts between street and lawn trees. Use of chemicals or mechanical ditching may kill or damage grass, trees, and shrubs close to the treatment site. By itself, severance of root grafts is also ineffective as a control method because it offers no defense to the main source of spread, e.g., beetle transmission.

Pressure injection of Lignasan BLP for the prevention or cure of fungus infection shows promise and has been used experimentally but needs further development and refinement with regard to dosage rate and application techniques before it can become a standard operational technique. Success with this technique has been variable and limited to trees with symptoms in less than 30 percent of the branches.

In the Northeast and South, most municipalities use only method #1, because of lack of money and the low percentage of elms remaining in the Northeast and the presence of many nonelm shade trees in the South. Many areas of the upper Midwest and West utilize methods #1 and #2.

Control Program 4/

Based on current knowledge and technology, a DED control program should include:

1. Continuous ground survey from the end of May through September.

2. Thorough sanitation--the elimination of all infected elm wood before beetles can develop and fly to healthy trees.

3. Protective chemical spray 5/--one application of methoxychlor in the spring.

4. Severance of root grafts between infected and adjacent healthy elms.

These control procedures are discussed in detail in the publication "Dutch Elm Disease and Its Control." 6/

4/ Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers--out of reach of children and pets.

NOTE: Registrations of pesticides are under constant review by the Environmental Protection Agency and the U.S. Department of Agriculture. Use only pesticides that bear a Federal registration number and carry directions for home and garden use.

5/ In some parts of the country, where the entire elm population is within the city area and thus permitting complete sanitation, chemical sprays may not be necessary.

6/ Schreiber and Peacock. See footnote 2, page 14.

Economic Justification for Dutch Elm Disease Control in Municipalities

The economics of DED impact on municipal resources must be examined in terms of the costs of removing and replacing dead trees, in depreciation of property values because of shade tree loss, and in control program costs. An expense occurs regardless of the action taken by a municipality having DED infected trees.

Cannon and Worley[7] examined the 15-year annual expenditures by 39 communities with DED-infected elms. In these communities the costs of control during the 15-year period were 37 to 76 percent less than the cost of removing dead trees where no control was attempted. Recognizing that control costs and program success varied considerably, Cannon and Worley used the annual cost extremes for active control programs to describe the range of costs within which all control programs might be expected to fall.

Cannon and Worley used cost data and performance data to develop a 15-year budget for three alternative courses of action.

1. Tree removal with no control--an estimate of the cost of doing nothing.

2. Tree removal with fair control performance using the highest costs from the cost range. Fair performance is achieved if no more than 5 percent of the elms die each year. This alternative gave an estimate of the highest average costs to be expected from an active control program.

3. Tree removal with the best control performance, using the lowest costs from the cost range. Best performance is achieved if no more than 1 percent of the elms die each year. This alternative gave an estimate of the lowest average costs to be expected from an active control program.

7/ Cannon, W.N., Jr., and D.P. Worley. 1976. Dutch elm disease control: performance and costs. USDA Forest Service Research Paper NE-345, 7 p., illus.

The costs for each alternative course of action plus 40 percent for administrative overhead were discounted at 6 percent and 10 percent to obtain the present value of the 15-year programs monitored by the Cannon and Worley study (appendix C). By dividing the present value of no control by the present value of each control alternative the following benefit-cost ratios for municipal control programs were developed:

	Discount Rate	
	6 percent	10 percent
Fair Control Performance	1.36:1.0	1.46:1.0
Best Control Performance	2.96:1.0	3.06:1.0

These ratios, therefore, represent the range in economic efficiency for control programs performed at an acceptable level of success compared to the cost of tree removal without control.

The implication of this analysis is that a DED control program which succeeds in maintaining an annual rate of elm mortality at 5 percent or less is economically justifiable. However, since the Cannon and Worley study derived data from a relatively small number of communities in a restricted geographic area, the results cannot be used to imply an economic justification for a national DED control program.

FEDERAL PARTICIPATION IN DUTCH ELM DISEASE CONTROL PROGRAMS

Federal Role

The Federal role in dealing with the Dutch elm disease is, under current policy, limited to carrying out research, publishing findings, conducting educational programs, and providing technical advice on control strategies to those who seek it. Efforts to halt the spread of the disease by quarantine were abandoned on the basis that the natural spread could not be practically prevented. Financial assistance for control projects has never been offered.

The procedure employed to identify or define a Federal role for insect and disease control programs under the authority of the Forest Pest Control Act (61 Stat. 177, as amended; 16 U.S.C. 594-1 to 594-5) evaluates the proposed project against a set of criteria which describe circumstances justifying Federal participation. The criteria used for forest insect and disease control programs require demonstration of: (1) international consequences; (2) national and regional economic impacts; (3) need for Federal coordination; (4) threat to Federal lands; (5) threat to unique resources; (6) distribution of benefits; or (7) other Federal role indicators such as a need for special technical expertise. One or more of the following Federal role criteria must be satisfied

before a proposed regulatory program against designated plant pests is established: (1) International implications likely; (2) important segment of agriculture and the general public adversely affected; (3) potential exists for a major agricultural threat; (4) interstate coordination required; or (5) Federal lands and interests threatened.

A national DED control program in municipal areas would represent a significant expansion of the current Federal role concept. The expanded Federal role would rest on the assumption that a significant reduction in the environmental quality of the Nation's towns and cities is being or will be caused by Dutch elm disease.

Too often, the specialized expertise and funds needed to minimize DED-caused tree mortality are lacking. Hence the disease continues to destroy the character and quality of many of the Nation's communities, as well as reducing property values.

Unless a coordinated effort can be mounted and additional funds made available to implement comprehensive protection programs directed at early control, the total number of native elms will continue to decline rapidly.

A federally sponsored program of technical assistance and extension education coupled with active State and municipal cooperation could provide the coordination necessary to develop effective DED control programs. Sources of additional funds would include each level of government from municipal through Federal.

The objective of a DED control program is to reduce the loss of elms to provide time for research to investigate alternative strategies for direct and indirect DED control. The passage of time will also permit the growth of nonsusceptible trees and disease resistant elms to shade tree size, reducing community dependence on DED-susceptible elms as a significant shade tree resource.

The degree of protection depends on the performance of the control program. We must recognize, however, that the fate of the municipal elm shade tree resource is not assured by the implementation of a control program. The DED is irrevocably established in most areas where elms are grown. Although current control techniques may reduce annual elm losses to as low as 1 percent, the continued loss of elms to the DED is a certainty.

Statutory Authority

The Department of Agriculture Organic Act of 1944 (58 Stat. 735, as amended; 7 U.S.C. 147a) authorizes the Secretary to carry out operations or measures to detect, eradicate, suppress, control, or to prevent or retard the spread of plant pests, including DED. This authority applies to urban and nonurban areas.

The Forest Pest Control Act (61 Stat. 177, as amended; 16 U.S.C. 594-1 to 594-5) restricts forest insect and disease control activities of the Department of Agriculture to forest lands. These programs are not authorized for urban areas.

The Cooperative Forest Management Act (64 Stat. 473, as amended; 16 U.S.C. 568c, 568d) establishes general authority to encourage the States to provide technical services for management, protection, and improvement of forest lands and the protection, improvement, and establishment of trees and shrubs in urban areas, communities, and open spaces. Payments are not currently provided for technical assistance expenditures for DED control in municipal areas.

The Smith-Lever Act of 1914 established the Cooperative Extension Service to conduct educational programs. Such programs are mutually agreed to by ES-USDA and the State Cooperative Extension Services.

Alternative Levels of Federal Participation

As requested this report discusses the Federal Government as a source of additional funds for control programs. The report should not be interpreted as advocating that Federal cost-sharing funds be provided.

There are approximately 34,000,000 elms still remaining in incorporated areas throughout the United States. Of these, approximately 1,390,000 are located in States where DED has not been reported and are not considered as immediately threatened (fig. 3).

In considering Federal participation in municipal DED control programs, the four principal areas of involvement are: (1) current level, (2) coordinated technical assistance and extension education, (3) revenue sharing, and (4) cost-sharing of control activities (see table 3).

Current Level

This level provides limited technical assistance and extension education in response to specific requests.

Expenditure reports indicate that 23 States are currently spending $18,726,020 on DED control (appendix D). Considering that a number of States did not report and others supplied incomplete data, it is estimated that current annual expenditures nationwide are about $30,000,000. Available data indicate that nationwide control costs average $17.10 per tree (appendix C). Hence, it is estimated that current control programs are providing some level of protection to approximately 1.754 million elms.

Coordinated Technical Assistance and Extension Education

Any program directed at minimizing losses due to DED will require technical assistance and Extension education to encourage municipalities already having control programs to increase the overall effectiveness of their efforts. This program will also advise nonparticipating communities of the benefits of taking action to prevent spread of the disease and provide them with training and assistance in planning and implementing a DED control program. By improving the control effort in some municipalities and encouraging others to initiate programs, it is estimated that this level will bring the number of trees receiving some protection to 1.929 million.

Eight new Federal and 56 State positions would be required to provide the needed technical assistance. (See appendix E for geographic breakdown of State positions.) Salary and associated support for these positions would require $3,360,000 annually in Federal and State funds based on 1977 operating expenses. This figure includes the cost of salaries, travel, office and laboratory facilities, and secretarial support and other administrative costs.

Revenue Sharing

Under current revenue sharing legislation, Federal funds are provided to some 39,000 State and local governments to be used at their discretion. During FY 1978, $6.855 billion will be allotted under this program. DED control activities could be financed from the Federal funds provided.

A recent amendment to the revenue sharing legislation permits the State and local governments to use dollars allotted under the program as matching funds for other Federal grant-in-aid programs. This could provide the stimulus needed to encourage more municipalities to participate in DED control programs.

Cost-Sharing

If Federal cost-sharing funds were available to offset the local cost of suppression, more suppression would be attempted. Experience in administering the Forest Pest Control Act indicates that the catalytic effect associated with such Federal participation stimulates additional expenditures in the non-Federal sector.

Assumptions

In developing figures for the number of elms to be protected and the associated costs under the several alternatives presented in table 3, the following assumptions were made:

--The number of elms protected under current programs where no Federal funds are involved was determined by dividing estimated annual expenditures by $17.10, the cost of protecting a tree. Control costs were calculated using $17.10 per tree protected and the total cost was subsequently determined by adding the cost of technical assistance.

--Additional Federal technical assistance to municipalities would increase the number of elms currently protected by 10 percent, or 175,000 additional trees. This increase is attributed to a modest heightening of public awareness of the need for and benefits of DED control. The 10 percent increase would be in addition to improving the effectiveness of ongoing control programs.

--Eight Federal and 56 non-Federal positions at $60,000 per position would be required to provide additional technical assistance. The cost per position includes salary, office and laboratory space, clerical support, other administrative costs, and travel expenses. The Federal Government would finance the State positions on a 50-50 matching basis.

--The maximum number of elms protected if the Federal Government assumed all control costs would be 24,458,000, or 75 percent of the 32,610,000 susceptible elms in areas now threatened by DED.

--Numbers of elms to be protected at the indicated levels of cost-sharing were calculated as a proportion of the difference between the maximum number of elms which could be protected if the Federal Government assumed all control costs and the number of elms protected by technical assistance only.

Table 3. Annual costs of DED control under alternative levels of Federal participation[1]

Alternative	Elms protected[2]	Total cost[3]	Federal cost[4]
	Number	Dollars	Dollars
Current level	1,754,000	30,000,000	0
Technical assistance and Extension education only	1,929,000	36,826,000	2,160,000
Technical assistance and Extension education plus 25 percent cost-share	7,561,000	133,133,000	34,483,000
Technical assistance and Extension education plus 33 1/3 percent cost-share	9,439,000	165,247,000	55,962,000
Technical assistance and Extension education plus 50 percent cost-share	13,193,000	229,440,000	114,960,000

1/ All Federal costs shown are in addition to State/municipal expenditures of revenue sharing funds.

2/ Determination of the number of elms protected is discussed in the preceding section on Assumptions.

3/ Total cost equals cost of technical assistance ($3,840,000) plus cost of control ($17.10 per tree protected).

Technical assistance costs include support for 8 Federal and 56 State positions at $60,000 per position.

4/ Federal cost equals Federal share of technical assistance (8 Federal positions plus 50 percent of 56 State positions at $60,000 per position) plus the Federal share of cost of control.

OUTREACH AND PUBLIC INFORMATION PLAN ON DUTCH ELM DISEASE

Situation

Cannon and Worley (see footnote 6, p. 22) reported, "Only those municipalities that conducted a high performance program could be expected to retain 75 percent of their elms for more than 20 to 25 years. Communities that experienced the fewest elm losses had a well founded program, applied it conscientiously and sustained their efforts over the years."

Major obstacles preventing municipalities from conducting high performance programs are the lack of education, technical assistance, and funds. This is verified in the Cannon and Worley report and information provided by several States.

Current Programs

Cooperative Extension personnel, primarily at State and country levels, have been performing some work on the Dutch elm disease problem for many years. This has been done primarily by Extension forestry and horticultural specialists and county Extension agents. As with other problems Extension responds to local requests for information. High priority commitments to production and marketing agriculture have tended to prevent concentrated and prolonged shade tree disease efforts especially by State Extension plant pathologists.

During the last 15 to 20 years most States have had one or more State Extension plant pathologists with a responsibility for working on many plant and crop disease problems. In some States, Extension work on shade tree diseases is combined with general work on shrubs, flowers, and lawn or turf diseases. Duties include diagnosis and clinics in the field, disseminating information, conducting training meetings, and other Extension work. Some States with limited resources have a general Extension plant pathologist with responsibility for all plant, crop, and shade tree diseases. Exact number of Extension person-year equivalents involved with Dutch elm disease is unknown, but is estimated to be approximately 15 to 20 (including county and State Extension personnel primarily).

Services available to communities through State Forestry agencies vary from State to State. The Colorado State Forestry Department, for example, has the primary responsbility for Dutch elm disease

information and education and technical assistance throughout the State. Staff foresters keep district personnel informed and trained; the district personnel in turn inform and train city personnel. All communities with Dutch elm disease, or adjacent to those communities with Dutch elm disease, are alerted to the problem and have the opportunity to receive training. In Minnesota, services administered by the Division of Forestry to urban areas are limited to distribution of literature and alerts through State and district offices. Many State forestry agencies fit within these two examples.

Through the Illinois and Ohio State forestry agencies, the Forest Service is cooperating with the cities of Elmhurst, Illinois, and Shaker Heights, Ohio, in Dutch elm disease pilot projects. The projects involve citywide evaluation of a promising systemic fungicide, Lignasan. In addition, the Forest Service, Agricultural Research Service, State agricultural experiment stations and universities provide information on the disease and its control as requested.

Action Plan

Objective

The objective of this plan is to inform communities, municipal governments, landowners, and individual homeowners of the history, incidence, severity, and control of DED, as well as inform them of the importance of controlling the disease. As indicated earlier in this report, DED can be controlled if communities are sufficiently motivated to diligently apply the recommended programs.

Areas of Emphasis

There are three broad geographical areas, each having a different degree of disease activity.

Area 1: Areas where the disease is already well established and has done considerable damage. This is largely in the Northcentral and Northeastern States. One of two situations exists:

a. People have ceased to be concerned and need motivation to renew and continue control efforts.

b. People are looking for ways to fight against the disease and need technical assistance and guidance to get a program established.

Area 2: Areas where the disease is becoming established. Example States are Minnesota and Colorado.

Area 3: Areas such as most Western States that have had no DED but need information in order to be watchful and prepared.

Community requirements for an education and public information action plan will vary among and within these areas.

With this in mind a flexible outreach and public information plan has been developed to support a Dutch elm disease control program (table 4).

The table displays the outreach activities to be developed. For each activity the applicable control areas, audience, agency(s) responsible, and duration are identified. Estimated cost for a 5-year outreach program is $2,555,000.

The program is designed to:

1. Motivate people to cooperate in a Dutch elm disease control effort.

2. Stress appropriate local and State organizational structures for educational purposes.

3. Involve local people in planning, conducting, and evaluating educational and control programs.

4. Demonstrate locally adapted Dutch elm disease control practices and educational programs in each of three areas of emphasis via pilot projects. (See areas 1, 2, and 3 as mentioned above).

5. Disseminate results of pilot projects to other States as needed.

6. Provide feedback to appropriate agencies of research needs on Dutch elm disease.

7. Strengthen local and State technical disease diagnostic services through appropriate training.

8. Coordinate Dutch elm disease control efforts with other local shade tree health and pest program efforts.

Table 4.--Outreach and Public Information Action Plan

NO.	WHAT	AREAS[1]/	TARGET AUDIENCE	WHO	HOW & COSTS[2]/	WHEN
1	Continue to update and apprise municipalities on research results and the need for sanitation treatment and on cost and benefit factors.	1&2	National Association of Counties, arborists and horticultural associations, and universities. To be used as outlets for public information.	ARS, CSRS, ES, FS, State Cooperative Extension Services (CES), and other State agencies.	Joint Department press releases.(a)	Continuing
2	Provide information on Dutch elm disease and the need for methods of control.	1,2&3	Urban parks and recreation departments, individual homeowners, and absentee landowners.	ARS, CSRS, ES, FS, State CES, and other State agencies.	Prepare and disseminate publications on the disease and its control. These will be tailored to each of the three areas.(b)	Fall 1978
3	Provide information on the availability of Federal-State cost-sharing programs for control.	1&2	Eligible participants to be identified.	Pending	Pending authorization of a cost-sharing program.	When implemented
4	Provide information about the development and testing of elm varieties resistant to DED and the availability of disease-resistant varieties and species.	1&2	State, county, and municipal governments and homeowners.	ARS, CSRS, ES, FS, State CES, and other State agencies.	Develop pictorial brochure and distribute. National press release on brochure from DC. Field office obtain exposure in weekly and daily papers.(c)	Release as information becomes available
5	Prepare radio and television public spots on DED; its severity, spread, and potential; and sources of technical information and assistance.	2&3	Local city government and homeowners. Release TV materials in selected cities and radio spots in rural areas.	ES, FS, State CES, and other State agencies.	Produce 60-second TV spots with USDA-MPS. Write and produce radio spots through USDA-RADIO-TV Office.(d)	Continuing

NO.	WHAT	AREAS[1/]	TARGET AUDIENCE	WHO	HOW & COSTS[2/]	WHEN
6	Inform public on how to identify DED and how to solicit for sanitation and control.	2&3	Municipal parks and recreation departments, homeowners, and large landowners. Also aim for general public.	ARS, CSRS, ES, FS, State CES, and other State agencies.	Produce pre-packaged media materials for coordinated mass media campaign. (e)	Continuing information program
7	Inform ornamental horticultural associations, environmental groups, consulting arborists, and foresters on detection, survey, and control of DED.	3	Members of associations and organizations who already have an interest in horticulture and urban forestry, State, county, and city agencies with parks and recreation programs.	ES, FS, State CES, and other State agencies.	Use associations' quarterly journals, newsletters, etc., as outlets to provide information on the spread of DED. (a)	Continuing basis
8	Conduct pilot education projects.	1,2&3	Community action programs involving citizens and local organizations.	ES, FS, State CES, and other State agencies.	Conduct extension education pilot projects in each of the three areas. (f)	Fall 1978

1/ See text for explanation of areas.

2/ Estimated total USDA costs on initial (first year) and continuing information outreach projects:

	Initial	5-year Continuing Program
(a) Use of existing agency funds	$ --	$ --
(b) Printing, revision, and reprinting	35,000	50,000
(c) Writing, layout, design, and print	35,000	30,000
(d) Write, produce, box, and distribute	40,000	30,000
(e) Write campaign mass media materials, layout, design, and print	75,000	80,000
Administrative overhead (1 man-year)	55,000	300,000
(f) Three extension education pilot projects	325,000	1,500,000
Total	$565,000	$1,990,000

Total Outreach Costs - $2,555,000.

APPENDIXES

APPENDIX A: List of State Agencies Contacted for DED Information

APPENDIX B: Current Research Funded by USDA

APPENDIX C: Economic Analysis Calculations

APPENDIX D: Annual Expenditures of 23 States Reporting on Dutch Elm Disease

APPENDIX E: Number of New State Positions Needed to Provide Technical Assistance for a National DED Program

Appendix A
List of State Agencies
Contacted for DED Incidence Information

Alabama

Department of Agriculture
and Industry
1445 Federal Drive
Montgomery, AL

Arizona

L. D. McCorkindale
State Entomologist & Director
Arizona Commission of
Agriculture & Horticulture
1624 W. Adams
Phoenix, AZ 85007

Arkansas

Robert Anderson, Director
State Plant Board
421 1/2 W. Capitol Avenue
Little Rock, AR 72203

California

California Department of
Food & Agriculture
1220 U Street
Sacramento, CA 95814

Colorado

John Laut
Staff Forester
Colorado State Forest Service
Colorado State University
CSFS Headquarters Bldg. #360
Foothills Campus
Fort Collins, CO 80523

Connecticut

John Anderson
State Entomologist
Connecticut Agricultural
Experiment Station
123 Huntington Street
New Haven, CT 06511

Delaware

Walter F. Gabel, State Forester
Forestry Section
Delaware Department of
Agriculture
Drawer "D"
Dover, DE 19901

Florida

Division of Forestry
Collins Building
Tallahassee, FL 32304

Georgia

Georgia Cooperative Extension Service
University of Georgia
Athens, GA 30601

Hawaii

Hawaii Department of Agriculture
1428 S. King Street
P.O. Box 5425
Honululu, HI 96814

Idaho

Director
Idaho Department of Lands
State Capitol Building
Boise, ID 83720

Illinois

Allan S. Mickelson
State Forester
Department of Conservation
605 State Office Building
Springfield, IL 62706

Indiana

John F. Datena, State Forester
Division of Forestry
613 State Office Building
Indianapolis, IN 46204

Iowa

Roy Hatcher
Forest Protection Forester
District 3, State Nursery
Box 823
Ames, IA 50010

Kansas

Dr. William Willis
Extension Plant Pathologist
Department of Plant Pathology
Kansas State University
Dickens Hall
Manhatten, KS 66506

Kentucky

Extension Service
School of Agriculture
Department of Plant Pathology
University of Kentucky
Lexington, KY 40505

Louisiana

Bureau of Entomology
and Plant Industry
Box 44153
Baton Rouge, LA 70804

Maine

John Chadwick
Maine Department of Conservation
Bureau of Forestry
State Office Building
Augusta, ME 04330

Maryland

Robert Altman
Maryland Department
of Agriculture
University of Maryland
College Park, MD 20742

Massachusetts

Stanley Wood, Chief
Bureau of Insect Pest Control
Division of Forests and Parks
Department of Natural Resources
100 Cambridge Street
Boston, MA 02202

Michigan

Daniel Mosher, Entomologist
Michigan Department of Natural Resources
Stevens T. Mason Building
Lansing, MI 48926

Minnesota

James Brooks, Pathologist
Department of Natural Resources
658 Cedar Street
Centennial Office Building
St. Paul, MN 55155

Mississippi

Cooperative Extension Service
Drawer EM
Mississippi State University
Mississippi State, MS 39762

Missouri

Osal B. Capps, State Forester
Missouri Conservation Department
Forestry Division
Jefferson City, MO 65101

Montana

Ray Bjornson
Administrator
Horticulture Division
Department of Agriculture
Helena, MT 59601

Nebraska

Dr. David Wysong
Extension Plant Pathologist
University of Nebraska
305 Plant Industry Bldg.
Lincoln, NE 68503

Nevada

Nevada State Department
of Agriculture
350 Capitol Hill Avenue
P.O. Box 11100
Reno, NV 89510

New Hampshire

Alfred Avery, Chief
Division of Forests and Lands
Department of Resources and
Environmental Development
P.O. Box 896
Concord, NH 03301

New Jersey

William M. Cranstoun, Director
Division of Plant Industry
Department of Agriculture
Box 1888
Trenton, NJ 08625

New Mexico

Donald Lucht
New Mexico Department
of Agriculture
Division of Plant Industry
Box 3189
Las Cruces, NM 88003

New York

E. G. Terrell, Principal Forester
Bureau of Forest Insect
and Disease Control
Department of Environmental
Conservation
Albany, NY 12201

North Carolina

Ralph C. Winkworth, Director
Division of Forest Resources
P.O. Box 27687
Raleigh, NC 27611

North Dakota

Dr. Robert Stack
Extension Plant Pathologist
N. Dakota State University
Department of Plant Pathology
Fargo, ND 58102

Ohio

Ernest J. Gebhart, Chief
Division of Forests and Preserves
Department of Natural Resources
Fountain Square
Columbus, OH 43224

Oklahoma

Elmer G. Peebles, Director
Forestry Division
122 State Capitol Building
Oklahoma City, OK 73105

Plant Industry and Entomology Division
122 State Capitol Building
Oklahoma City, OK 73105

Oregon

William Kosesan
Assistant Chief
Plant Division
Oregon Department of Agriculture
Salem, OR 97310

Pennsylvania

James O. Nichols, Chief
Forest Pest Management
Bureau of Forestry, DER
34 Airport Drive
Middletown, PA 17057

Rhode Island

Rudy D'Andrea, Chief
Division of Agriculture
Veterans Memorial Building
83 Park Street
Providence, RI 02903

South Carolina

Extension Service
Department of Plant Pathology
and Physiology
Clemson University
Clemson, SC 29631

South Dakota

Bruce Webster
Community Forester
S. Dakota State Division of
Forestry
Box 1292
Pierre, SD 57501

Tennessee

Max J. Young, State Forester
Division of Forestry
2611 West End Avenue - Room 302
Nashville, TN 37203

Texas

Paul R. Kramer, Director
Texas Forest Service
College Station, TX 77843

Utah

Utah State Department
of Agriculture
State Capitol Building
Salt Lake City, UT 84111

Vermont

W. Brenton Teillon, Chief
Forest Resource Protection
Agency of Environmental
Conservation
Department of Forests and Parks
State House
Montpelier, VT 06502

Virginia

Extension Service
Department of Plant Pathology & Physiology
VPI & State University
Blacksburg, VA 24061

Washington

Dr. Otis Maloy
Department of Plant Pathology
Washington State University
State Department of Agriculture
Pullman, WA 99163

West Virginia

Albert E. Cole, Director
Plant Pest Control Division
West Virginia Department of Agriculture
Charleston, WV 25305

Wisconsin

Allan Prey, Pathologist
Nevin Hatchery
Route #2
Madison, WI 53713

Wyoming

Herb Cottrell
Assistant State Forester
Wyoming State Forestry Division
113 Capitol Building
Cheyenne, WY 82002

Appendix B

Current Research Funded by USDA

Research programs supported by the Agricultural Research Service, Cooperative State Research Service, and Forest Service. The appendix was compiled from information provided by the respective agencies.

Agricultural Research Service

Locations:

North Central Region, Nursery Crops Research Laboratory Delaware and Wooster, Ohio. L. R. Schreiber, Acting Research and Locations Leader
Project: Nature and Control of Dutch Elm Disease and Other Shade Tree Diseases

U.S. National Arboretum, Washington, D. C.
F. S. Santamour, Jr., Supervisory Research Geneticist
Project: Breeding and Production--Florist and Nursery Crops

Research Studies:

1. Development, propagation, and evaluation of elm clones resistant to DED--L. R. Schreiber, A. M. Townsend, and F. S. Santamour, Jr.

2. Chemical control of DED--L. R. Schreiber and C. L. Wilson.

3. Biological control of DED--L. R. Schreiber and C. L. Wilson.

4. The nature and role of variability of *C. ulmi* in disease incidence, severity, and chemical tolerance--A. M. Townsend and C. L. Wilson.

5. The role of water stress on disease development--L. R. Schreiber.

6. Control of root-graft spread of DED--L. R. Schreiber.

7. Tree propagation studies--L. R. Schreiber and A. M. Townsend.

Cooperative State Research Service

Location and Studies

Colorado State University

Project: Dutch Elm Disease--J. W. Brewer.

Studies:

1. Nature of resistance among clones and hybrids of DED resistant elms.

2. Types and levels of parasites and predators of the European elm bark beetle in Colorado.

Connecticut Agricultural Experiment Station

Project: Biological and Chemical Control of DED--J. E. Elliston and S. Rich.

Studies:

1. DED control with systemic chemicals.

2. Induced resistance to DED in American elm with non-virulent mutants of *C. ulmi* and related fungi.

Cornell University

Project: Biology and Control of Vascular Diseases of Trees--W. A. Sinclair.

Studies:

1. Systemic fungicides for the control of vascular diseases.

Project: Pathology of Wilt Diseases of Trees--W. A. Sinclair.

Studies:

1. Selection and screening of wilt resistant strains of the American elm.

University of Illinois

Project: Etiology, Epidemiology and Control of Vascular Diseases of Trees and Shrubs--D. Neely.

Studies:

1. Control of DED with systemic fungicides.

University of Maine

Project: Pathology of Wilt Diseases of Trees--R. Campana.

Studies:

1. Fungicide injection and pruning for DED therapy.

2. Microbial antagonism to C. ulmi.

3. Influence of host anatomy on pathogen growth, development, movement, and damage.

University of Massachusetts

Project: Pathology of Wilt Diseases of Trees--F. W. Holmes and T. A. Tattar.

Studies:

1. The genetics of pathogenicity and virulence variability in C. ulmi.

2. Propagation and DED resistance testing of elms from thermal neutron irradiated seed.

3. Systemic fungicide for DED therapy.

Michigan State University

Project: Disease Problems of Woody Plants--J. Hart.

Studies:

1. Fungicide sprays for DED control.

2. Propagation and release of elm bark beetle parasites.

3. Selection of DED resistant elms.

University of Minnesota

Project: Control Programs for DED and Oak Wilt--D. W. French.

Studies:

1. Chemical exclusion of elm bark beetles from diseased elm logs.

2. Aerial photography for DED detection and evaluation.

Project: Elm Bark Beetle Populations Important to Sanitation Measures in DED--T. C. Skalbeck.

Studies:

1. Mortality factors in elm bark beetles.

2. Elm bark beetle surveillance with pheromone-baited traps.

Virginia Polytechnic Institute

Project: Physiological Processes Associated with the Causes and Control of Tree Diseases--R. J. Stipes.

Studies:

1. The nature and causes of virulence variability in *C. ulmi*.

University of West Virginia

Project: Pathology of Wilt Disease of Trees in the Northeast--W. L. McDonald.

Studies:

1. The nature and causes of virulence variability in *C. ulmi*.

Project: Biology and Control of Vascular Disease of Trees--W. L. McDonald and D. F. Hindol.

Studies:

1. Variation in pathogenicity in *C. ulmi*.

University of Wisconsin

Project: The Nature of DED Resistance in *Ulmus*--E. B. Smally and D. T. Lester.

Studies:

1. The nature of resistance to DED in elms.

2. Selection, breeding, and testing of DED resistant American elms and elm hybrids.

3. DED control with systemic fungicides.

Forest Service

Location

Northeastern Forest Experiment Station, Forest Insect and Disease Laboratory, Delaware, Ohio.

Project: Insect Vectored Vascular Wilts of Forest Tree Species--J. W. Peacock, Project Leader.

Studies:

1. Systemic fungicides and pruning for DED therapy--G. F. Gregory.

2. Pheromone baited trapping systems for elm bark beetle suppression and DED control--R. A. Cuthbert and J. W. Peacock.

3. Elm bark beetle detection and population surveillance with pheromone-baited traps--R. A. Cuthbert and J. W. Peacock.

4. Effects of synthetic beetle pheromone and trapping programs on non-target insects--B. H. Kennedy and J. W. Peacock.

5. Propagation and release of elm bark beetle parasites and their impact on beetle populations--B. H. Kennnedy.

6. Elm bark beetle biology and behavior--R. A. Cuthbert and E. H. Wollerman.

7. Improvement and evaluation of insecticide spray practices--J. H. Barger.

8. Improvement and evaluation of elm sanitation practices--J. H. Barger.

9. Economic analysis of DED control treatments and programs--W. N. Cannon, Jr.

10. Elm bark beetle feeding inhibitors from non-host trees--J. W. Peacock.

11. Beetle dispersal in response to pheromone--E. H. Wollerman.

12. Control of root-graft spread of DED--J. H. Barger.

Forest Service Supported Cooperative Aid Agreements With Universities

State University of New York

College of Environmental Science and Forestry

Project: Mass trapping of *Scolytus multistriatus* on pheromone-baited traps to control DED--G. N. Lanier, J. B. Simeone, and R. M. Silverstein.

Studies:

1. Test effectiveness of pheromone-baited traps in reducing incidence of DED in small isolated clones of high value elms.

2. Perfect trapping systems.

University of California at Davis

Project: Evaluation of trap-out strategy for management of *Scolytus multistriatus* populations in California--M. C. Birch.

Studies:

1. Methods to reduce or eliminate populations of *Scolytus multistriatus* from small communities in eastern California by various modifications of grid trapping.

APPENDIX C

Economic Analysis Calculations

The most complete data available for use in developing an estimated economic efficiency analysis for Dutch elm disease (DED) control programs are provided in the Cannon and Worley Report [1]. Their analysis of the economic impact of control measures for a 15-year period dealt with the cost and performance (control success) for three alternatives based on a 1,000-tree unit (table 5).

The three alternatives utilized were (1) no control, (2) fair control performance at the highest cost, and (3) the best control performance at the lowest cost. Fair control performance is achieved if no more than 5 percent of the elms die each year. Best control performance allows no more than 1 percent mortality. High and low control costs were derived from an analysis of the range of 1972 costs for individual jobs comprising the municipal DED control program. The jobs included tree removal, sanitation, spraying, root-graft control, and survey. In 1972 dollars the control costs based on a 1,000-tree unit were $8.80 per elm tree in the population. By adding 30 percent to compensate for inflation, and including replacement costs of $0.75 per tree, the 1977 control costs become $12.20 per tree in the population. Addition of 40 percent for overhead raises the cost to $17.10 per tree. The cost of the no-control alternative includes removal of dead trees and property value depreciation resulting from the loss of shade trees. The cost of the control alternatives includes treatment and removal costs plus property value depreciation attributed to shade trees lost.

1/ Cannon, W. N., Jr., and D. P. Worley. 1976. Dutch elm disease control: performance and costs. USDA Forest Service Research Paper NE-345, 7pp., illus.

Table 5.--Present values of no control and control costs[2/]

Year	No Control Costs	Discounted 6 Percent	Discounted 10 Percent	Fair Control Costs	Discounted 6 Percent	Discounted 10 Percent	Best Control Costs	Discounted 6 Percent	Discounted 10 Percent
	(Thousands)								
1	$ 2.1	$ 1.98	$ 1.91	$ 4.8	$ 4.53	$ 4.36	$2.7	$ 2.55	$ 2.45
2	4.2	3.74	3.47	5.0	4.45	4.13	3.1	2.76	2.56
3	10.5	8.82	7.89	5.9	4.95	4.43	3.6	3.02	2.70
4	16.8	13.31	11.47	7.8	6.18	5.33	3.6	2.85	2.46
5	22.9	17.11	14.23	7.8	5.83	4.84	5.0	3.74	3.10
6	25.2	17.76	14.22	7.8	5.50	4.40	5.0	3.52	2.82
7	33.3	22.15	17.09	8.7	5.79	4.46	5.0	3.32	2.56
8	23.5	14.74	10.96	9.8	6.15	4.57	5.0	3.14	2.33
9	22.9	13.55	9.71	10.4	6.16	4.41	5.0	2.96	2.12
10	10.4	5.81	4.01	14.6	8.15	5.63	5.0	2.79	1.93
11	6.2	3.27	2.17	14.6	7.69	5.12	5.9	2.63	1.75
12	2.2	1.09	0.70	15.1	7.50	4.81	4.8	2.38	1.53
13	2.2	1.03	0.64	14.8	6.94	4.29	4.5	2.11	1.30
14	1.4	0.62	0.37	14.3	6.32	3.77	5.9	2.61	1.55
15	1.4	0.58	0.34	14.6	6.09	3.49	5.0	2.09	1.20
Present value		$125.56	$99.18		$92.23	$68.04		$42.47	$32.36

2/Cannon and Worley, p. 5, fig. 3

APPENDIX D

Annual Expenditures
of 23 States Reporting
for Dutch Elm Disease

STATE	ANNUAL EXPENDITURE
California	$ 2,200,000
Colorado	963,000
Idaho	60,000
Indiana	250,000
Iowa	429,000
Kansas	400,000
Maine	50,000
Massachusetts	2,036,000
Michigan	18,000
Minnesota	6,460,000
Missouri	1,800,000
Montana	200
New Hampshire	84,000
New York	525,000
North Dakota	143,000
Ohio	60,000
Oregon	5,000
Pennsylvania	65,000
South Dakota	70,000
Vermont	100,000
West Virginia	3,000
Wisconsin	3,000,000
Wyoming	4,820
Total	$18,726,020

APPENDIX E

Number of New State Positions Needed to Provide Technical Assistance for a National DED Program[1/]

State	Currently Needed	Potentially Needed
Alabama	1	
Alaska	None	
Arizona		1
Arkansas	3	
California	2	
Colorado	2	
Connecticut	1	
Delaware	1	
Florida		1
Georgia	1	
Hawaii	None	
Idaho	1	
Illinois	1	
Indiana	1	
Iowa	1	
Kansas	1	
Kentucky	1	
Louisiana		1
Maine	1	
Maryland	1	
Massachusetts	1	
Michigan	1	
Minnesota	4	
Mississippi	1	
Missouri	2	
Montana	1	
Nebraska	1	
Nevada		1
New Hampshire	1	
New Jersey	1	
New Mexico		1
New York	1	
North Carolina	4	
North Dakota	1	
Ohio	1	
Oklahoma	1	
Oregon	1	
Pennsylvania	1	
Rhode Island	1	
South Carolina	1	
South Dakota	1	
Tennessee	1	
Texas	3	
Utah		1
Vermont	1	
Virginia	2	
Washington		1
West Virginia	1	
Wisconsin	2	
Wyoming	1	
Total	56	7

1/ The number of positions needed is determined by the amount of elms requiring protection within a State--1 million elms or less = 1, 1-2 million elms = 2, 2-3 million elms = 3, and greater than 3 million elms = 4.

GPO 918-976